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A low carbon society outlook for Malaysia to 2035

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ABSTRACT

This paper presents a quantitative analysis of a low carbon society outlook for Malaysia to 2035. Findings in the Reference scenario, where current policies are extended throughout the projection period, depict an unsustainable development given an increasing spending on fossil fuels energy imports for coal in particular, and for oil and gas in the near future. While the use of fossil fuels is projected to rise, carbon dioxide (CO_2) emissions will be increasing accordingly. An alternative scenario which promotes the introduction of Advanced Technologies demonstrates how a more extensive use of renewable energy sources and the promotion of energy efficiency across all sectors could effectively address an over reliance on fossil fuels while reducing CO_2 emissions.

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1. Introduction

Since its independence, Malaysia's economy has been experiencing a rapid growth which can be attributed to the success of the 1985 Industrialization Plan that brought forth a rapid structural transformation, away from the once agriculture-oriented economy. A period of sustained high economic growth lasted until the Asian Financial Crisis in 1997–1998 [1]. Malaysia's annual growth averaged almost 8% from the early 1980s through to the mid-1990s and for the entire period from 1980 to 2007, real gross domestic product (GDP) grew at an average of 6.1% per year. Such rapid and fundamental change to the economy, away from agriculture and towards more industrialization, resulted in a faster rate of increase on energy use than GDP. Primary energy consumption grew at 7.3% p.a., increasing from 11 million tons of oil equivalent (Mtoe) in 1980 to 70 Mtoe in 2007 [2]. The Malaysian energy mix relies predominantly on fossil fuels with oil as the main source of supply until it was gradually replaced by gas, following the introduction of the Fourth Fuel Diversification Strategy in 1981 [3]. In recent years, a further transition from gas to coal took place, driven primarily by a governmental policy that favors the use of coal for electricity generation.

Apart from promoting transition amongst fossil fuels, the Malaysian government also placed a great importance on the development of alternative fuels, in particular renewable energy such as biomass, solar and biodiesel. The Fifth Fuel Diversification

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Strategy, introduced in 2000, recognized the potential of biomass, biogas, solar and other renewable energy resources within Malaysia. The Diversification Strategy was followed by a series of promoting projects including the Small Renewable Energy Power Program (SREP) in 2001, the Biomass-based Power Generation and Cogeneration in the Palm Oil Industry (BioGen) in 2003, the Malaysia Building Integrated Photovoltaic Technology Project (MBIPV) in 2005, as well as a new policy direction to promote the use of biofuel with the National Biofuel Policy of 2006. The announcement of the National Green Technology Policy (NGTP) in 2009 reaffirmed the government's intention to accelerate the development of renewable energy or *Green Technology* at large, not only for energy security reason but also as an important driver of future economic growth [4].

In addition to conserving domestic fossil resources and promoting renewable energy sources, the government also pursued energy efficiency improvements as one of the strategic steps towards energy security. The Malaysia Industrial Energy Efficiency Improvement Project (MIEEIP) of 1999, the Building Sector Energy Efficiency Project (BSEEP) of 2009, and the Industrial Energy Efficiency for Malaysian Manufacturing Sector (IEEMMS) are a few examples of projects that promote the efficient use of energy in the industry and building sectors [5].

In 2010, the government formulated its New Energy Policy under the Tenth Malaysia Plan 2011–2015 with the objectives to further pursue energy security, energy efficiency as well as reduce carbon dioxide (CO_2) emissions. Amongst the objectives, the New Energy Policy is targeting a 5.5% contribution from renewable energy in the electricity generation mix by 2015 and further energy efficiency improvements in the household, industry and building sectors.

Malaysia is endowed with fossil fuel resources. Setting aside the small amount of gas supplied from the Malaysia-Thai Joint Development Area (MTJDA) and the West Natuna gas field of Indonesia [6], demand for oil and gas has been met primarily with domestic resources. Nonetheless, over a long term perspective, the need and urgency to diversify the fuel mix away from a high dependency on fossil fuels is emerging. An efficient use of energy in order to attain energy security and conserve the limited indigenous fossil reserves must be promoted.

This paper aims to perform a quantitative analysis on a low carbon society outlook for Malaysia to 2035, in the context of a comprehensive adoption of "fossil fuel free" measures which include enhanced utilization of renewable energy for power generation and as transport fuels, improved energy efficiency for industrial processes and household appliances, and thermal efficiency of electricity generation.

This paper is organized as follows: Section 2 provides an overview of the integrated econometric model used for this study and a summary of the key findings under the *Reference scenario* outlook of Malaysian energy system. Section 3 analyzes the role of technology progress and renewable energy in addressing energy security as well as environmental issues through an alternative scenario, the *Technologically Advanced scenario*. Section 4 provides suggestions on sustainable energy strategies and Section 5 gives the conclusion.

2. Long term energy outlook of Malaysia to 2035

2.1. Model structure, methodology and scenario design

This study updates our 2008-study on the macroeconomic and energy outlook of Malaysia to 2030. For consistency, results of this analysis were derived with revision to the integrated econometric model utilized in our 2008-study [7]. An econometric model is one of the useful tools in developing long term macroeconomic and energy projections. Komiyama et al. [8,9], Komiyama [10], ADB [11], APERC [12] and Li [13,14] are a few examples of other recent projection studies also using econometric models.

The model now consists of 198 equations with 46 equations for the macroeconomic sub-model, and 152 equations for the energy-environment sub-model. As in the past, the equations are either defined or econometrically estimated using the ordinary least squares (OLS) method with historical data from 1960 to 2007 for macro and from 1971 to 2007 for energy related statistics. The projection period for this study was extended from 2030 until 2035.

As in the past, this study developed its own macroeconomic outlook for Malaysia till 2035, from which the Reference and the Technologically Advanced scenarios are both developed to examine future energy trends. The Reference scenario simulates current trends and policies as implemented in Malaysia by the end of 2007, assuming its continuation till 2035.

As for the alternative scenario, our study in 2008 focused on the use of renewable energies, such as biomass for power generation and B5 biodiesel in transportation, to examine their implications on future demand and supply for fossil fuels, as well as CO_2 emissions of Malaysia to 2030. In this study, the Technologically Advanced scenario assumes an accelerated deployment and transfer of advanced technologies alongside of supportive governmental policies directed towards the adoption of such technologies.[1] This scenario aims to assess the role of renewable energy and technology progress to future Malaysia's energy system and CO_2 emissions to 2035, based on a set of key assumptions summarized in part B of Table 1. For electricity generation, the Technologically Advanced scenario assumes a much wider utilization of renewable energy such as solar, biomass, biogas, solid waste and mini hydro, while taking into account the potential availability for each of these resources and to a lesser extent investment costs.[2] It also considers nuclear power as one of the long term options in fulfilling future electricity needs in Malaysia post 2030 [22,23]. For the transportation sector, in addition to the B5 blend that began in 2011, further improvements of vehicle fuel efficiency and the penetration of clean energy vehicles including hybrid and electric vehicles were adopted, using the JAMA-Model developed by IEEJ [24]. The potential savings from energy efficiency cover electricity generation, industry, household and commercial sectors. On electricity generation, coal-fired efficiency improves from an average of 39% in the Reference scenario to 42% in the Technologically Advanced scenario, whereas gas-fired power plant efficiency improves from 48% to 49% in 2035. The extent of potential industrial efficiency improvements differs by sub-sectors and is affected by the infrastructure in place. Due to limitation of data availability on specific industry sub-sectors, the overall energy intensity for the entire industry sector is assumed to be 10% lower than that of the Reference scenario. Regarding household and commercial sectors, energy savings are anticipated to come principally from efficiency improvement of air-conditioners. The analysis also considers potential CO_2 abatement with carbon capture and storage (CCS)

[1] Analysis on energy related costs and investments necessary to achieve higher levels of energy efficiency, wider use of renewables and deployment of advanced technologies that would be needed to realize the outcomes is not covered in this study. A comprehensive analysis on the prospect of palm biodiesel in Malaysia including cost is available in Gan and Li [15].

[2] Learning curve (or experience curve) is one of the important and widely used tools to forecast diffusion of renewable energy technologies [16–21]. Theoretically, a learning curve would identify the contributing factors to cost reduction over time, as technology is maturing. In Malaysia, however, the use of renewable energy such as solar photovoltaic only began in 2005, and there is no wind application. Hence there is insufficient historical cost data to support the use of learning curves in our analysis at this moment.

Table 1
Key assumptions for macroeconomic and energy outlook.

Part A : Macroeconomic related	2007–2020	2020–2030	2030–2035	2007–2035	
I. Variables (annual growth rate, %)					
Population	1.5	1.0	0.8	1.2	
Government consumption	4.0	3.0	2.0	3.3	
Government investment	4.5	3.0	2.0	3.5	
World trade	3.5	3.5	3.5	3.5	
II. Variables (level)	Actual 2007	2010	2020	2030	2035
Crude oil prices (USD/BBL)	68.3	52.3	114.3	159.6	188.6
Part B : Energy related	Actual 2007	Reference scenario (RS) 2035	Technologically Advanced scenario (TA) 2035		
I. Assumptions on energy saving					
Thermal efficiency (%)					
Coal-fired	34	39	42		
Gas-fired	40	48	49		
Efficiency in final energy consumption sectors					
Industrial		RS	Improved by 10%		
Household		RS	Improved by 10% (1)		
Commercial		RS	Improved by 25% (1)		
II. Assumptions on power generation (MW)	Actual 2008/2009	2035 (RS)	2035 (TA)	Potential	
Renewable sources					
Solar	0.612	2600	6500	6500 (2)	
Biomass	30.0	780	1300	1300 (3)	
Biogas	2	50	100		
Solid waste	5.5	100	400	400 (3)	
Wind	0.0	0	5	Low wind speed (3)	
Mini hydro	*included in hydro*	190	490	490 (4)	
Hydro	2091.7	8298	13356	29,000 (5)	
Nuclear	0.0	0	2000		
III. Assumption for transport sector	Actual 2007	2035 (RS)	2035 (TA)		
B5 blend (beginning 2011)	0	50% of trucks, bus, etc	100% of trucks, bus, etc		
Fuel efficiency, and alternative fuel vehicles		RS	Adopted from JAMA-Model [24]		

Compile from: [22,24,26–32].
(1) Air-conitioner accounts for 21% of household electricity use, and 64% of commercial electricity use. Indicates overall savings for each sector assuming 50% improvement in Coefficient of Performance (COP) of air-conditioner by 2035.
(2) Estimation based on suitable building roof surfaces of houses and commercial buildings in Malaysia.
(3) Estimation by Energy Commission of Malaysia.
(4) As quoted in Haris [29].
(5) Economic potential.

Table 2
Malaysia macroeconomic outlook to 2035.

GDP by sector	**Billion USD at constant 2000 price**						**Share** (%)			**Average annual growth** (% **p.a.**)			
	1990	2007	2010	2020	2030	2035	2007	2020	2035	1990–2007	2007–2020	2020–2035	2007–2035
GDP	47	133	156	240	358	432	100	100	100	6.3	4.7	4.0	4.3
Primary	7.4	10	11	14	18	20	7.6	6.0	4.6	1.9	2.7	2.2	2.4
Industry	20	59	70	98	138	163	45	41	38	6.7	3.9	3.5	3.7
Service	20	64	75	128	202	249	48	53	58	7.1	5.5	4.5	5.0
Macro indicators													
Per capita GDP (USD/capita)	2551	4884	5439	7307	9891	11,488				3.9	3.1	3.1	3.1
Per capita GDP, PPP terms (USD/capita)	5891	10,386	11,569	15,541	21,037	24,433				3.4	3.1	3.1	3.1
Vehicle ownership rate (%)	9%	25%	26%	31%	34%	36%				5.8	1.8	1.0	1.4

technologies and assumes that all new coal-fired capacity added post 2030 will be fitted with CCS [25]. As an oil and gas producing country, the injection of CO_2 could further enhance oil recovery in existing wells, thus providing additional energy, economic and environmental benefits.

The key assumptions for the macroeconomic outlook are summarized in part A of Table 1. Future crude oil price trends are adopted from IEEJ Asia-World Energy Outlook 2009 [24]. Key assumptions for energy related simulations in the Reference and the Technologically Advanced scenarios are summarized in part B.

2.2. Macroeconomic outlook

Malaysia's economy is expected to grow at an annual average of 4.3% from 2007 to 2035, as showed in Table 2. For the period 2007–2020, the average economic growth is projected to be around 4.7% while for the period after 2020, it will slowly decelerate to an average of 4%. The size of real GDP in constant 2000 price is expected to reach US$432 billion in 2035 compared with US$133 billion in 2007. Per capita real GDP will increase to US$11,488 in 2035, up from US$4884 in 2007; in purchasing power parity (PPP) terms, it will reach US$24,433 in 2035 compared with US$10,386 in 2007. Looking at the macroeconomic structure, the share of the service sector is anticipated to increase substantially from 48% in 2007 to 58% in 2035, reflecting the continuation of the established trend for restructuring Malaysia's economy away from primary and industry sectors towards services and high value-added products. Growth in services is anticipated from finance, insurance, real estate and business services, wholesale and retail trade, accommodation and

Table 3
Malaysia total primary energy demand by fuel to 2035 in the Reference scenario.

	Mtoe						**Share (%)**			**Average annual growth (% p.a.)**			
	1990	2007	2010	2020	2030	2035	2007	2020	2035	1990–2007	2007–2020	2020–2035	2007–2035
Total primary energy demand	21	70	75	99	128	145	100	100	100	7.5	2.8	2.5	2.6
Fossil fuels	20	69	74	98	125	142	100	99	98	7.5	2.7	2.5	2.6
Coal	1.0	8.9	10	16	25	30	13	16	21	13.4	4.8	4.3	4.5
Oil	12	26	28	35	42	45	37	35	31	4.4	2.3	1.8	2.0
Gas	6.8	35	36	47	59	66	50	47	46	10.1	2.4	2.3	2.3
Hydro	0.3	0.6	0.6	1.1	1.7	2.2	0.8	1.1	1.5	2.9	5.0	5.0	5.0
Renewables	0	0	0.1	0.4	0.6	0.8	0	0.4	0.6	0.0	91.0	4.6	38.3
Nuclear	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0
Energy indicators													
Energy-GDP intensity (toe/million constant RM2000)	115	138	126	109	94	88	–	–	–	1.1	−1.8	−1.4	−1.6
Energy-GDP elasticity	–	–	–	–	–	–	–	–	–	1.2	0.6	0.6	0.6
Per capita energy (toe/capita)	1.2	2.6	2.6	3.0	3.5	3.8	–	–	–	4.8	1.3	1.6	1.5
CO_2 emissions ($MtCO_2$)	56	188	210	281	365	414	100	100	100	7.4	3.1	2.6	2.9
Coal	4.1	35	40	64	99	121	19	23	29	13.4	4.8	4.3	4.5
Oil	37	77	85	106	127	138	41	38	33	4.3	2.6	1.8	2.1
Gas	15	76	85	110	139	155	41	39	38	10.3	2.9	2.3	2.6

restaurants, as well as transport and communication subsectors. Accordingly, the share of the industry sector to GDP is expected to decline from 45% in 2007 to 38% in 2035 and the primary sector will further decline from 8% in 2007 to less than 5% in 2035. On an expenditure basis, private consumption will continue to be an important driver of future growth, on account of better commodity prices, a resilient employment market and favorable financing facilities. Additionally, exports which contributed approximately 15% of GDP in 2007 will remain a key contributing factor to the future growth of Malaysia's economy. In light of the generally favorable outlook for the Chinese economy, Malaysia is well positioned with a positive export outlook for liquefied natural gas, various palm oils and manufacturing products. As a result of a sustained economic growth and improved standard of living, the total number of road vehicles will double from 6.7 million in 2007 to 13.5 million in 2035. Correspondingly, the vehicle ownership rate is anticipated to climb from 25% in 2007 to 36% in 2035.

2.3. Energy outlook in the references scenario

In the Reference scenario, total primary energy demand (TPES) is anticipated to increase by an average of 2.6% per year between 2007 and 2035, reaching 145 Mtoe in 2035, doubling the 70 Mtoe required in 2007, as showed in Table 3. Fossil fuels will remain the dominant source of primary energy to Malaysia, accounting for nearly 97% of the overall increment between 2007 and 2035. Its aggregate share to TPES, however, will fall marginally to 98% in 2035. In volume terms, gas will show the largest increment, accounting for 42% of the total increase in TPES between 2007 and 2035, followed by coal and oil at 29% and 26% respectively. Over the projection period, gas will grow by 2.3% per year and its share to TPES will drop gradually from just below 50% in 2007 to 46% in 2035, as a result of a further shift to coal in electricity generation. Primary demand for oil is expected to grow by 2% per year between 2007 and 2035, increasing from 26 Mtoe in 2007 to 45 Mtoe by 2035, driven mainly by a higher motorization rate projected to reach 36% in 2035, up from 25% in 2007. In the Reference scenario, oil will remain one of the important sources of energy, maintaining a share above 30% in 2035. Coal, on the other hand, will be the fastest growing fuel among the fossil fuels used in Malaysia, increasing by 4.5% per year between 2007 and 2035. Its growth is primarily due to a supportive governmental policy which favors its use for power generation as a means to reduce an over reliance on gas. Contribution of hydro, renewable and nuclear collectively will remain moderate at 2% of TPES in 2035, a marginal increase from just below 1% in 2007.

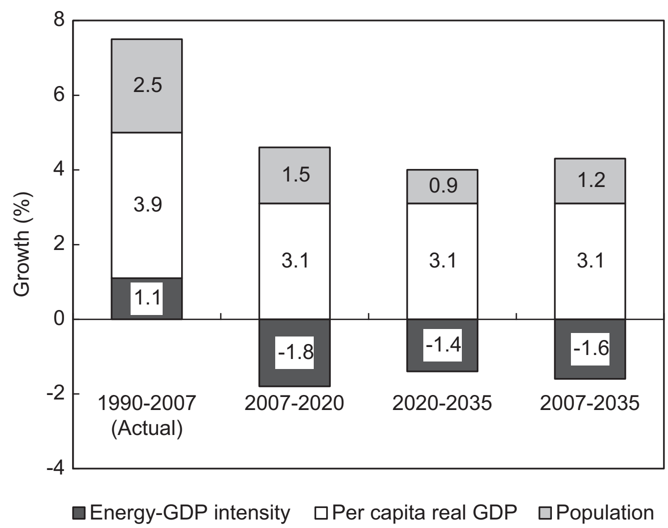

Fig. 1. Decomposition analysis of total primary energy demand growth in the reference scenario.

CO_2 emissions in the reference scenario are anticipated to increase sharply from 188 million tons of carbon dioxide ($MtCO_2$) in 2007 to 414 $MtCO_2$ in 2035, growing faster than the TPES growth, at an average of 2.9% throughout the projection period. CO_2 emissions from coal will grow the fastest, reaching 121 $MtCO_2$ by 2035 and account for 29% of total emissions owing to its increase use principally for electricity generation.

In the reference scenario, population growth and improved living standards will remain the principal drivers to future energy needs as showed in Fig. 1. Per capita energy consumption will increase from 2.6 toe in 2007 to 3.8 toe in 2035. Meanwhile, the energy-GDP intensity (measured by the ratio of TPES over GDP at constant 2000 price) will increase by an average of 1.6% p.a. between 2007 and 2035, partly offsetting the effects of rising population, urbanization and growing wealth.

In the reference scenario, the aggregate energy use of all end-use sectors, namely industry, transport and others, is projected to grow by 2.7% per year through to 2035, slightly faster than that of primary energy demand as showed in Fig. 2.

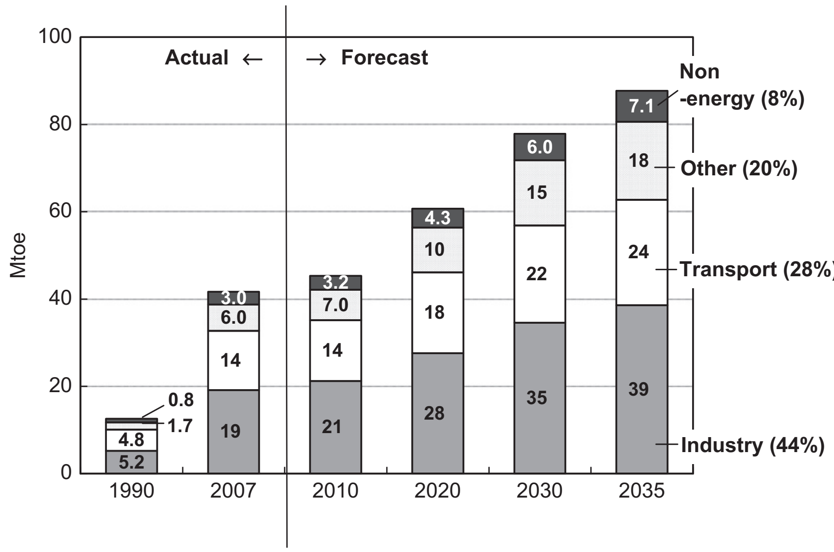

Fig. 2. Malaysia final energy demand by sector to 2035 in the reference scenario (Mtoe).

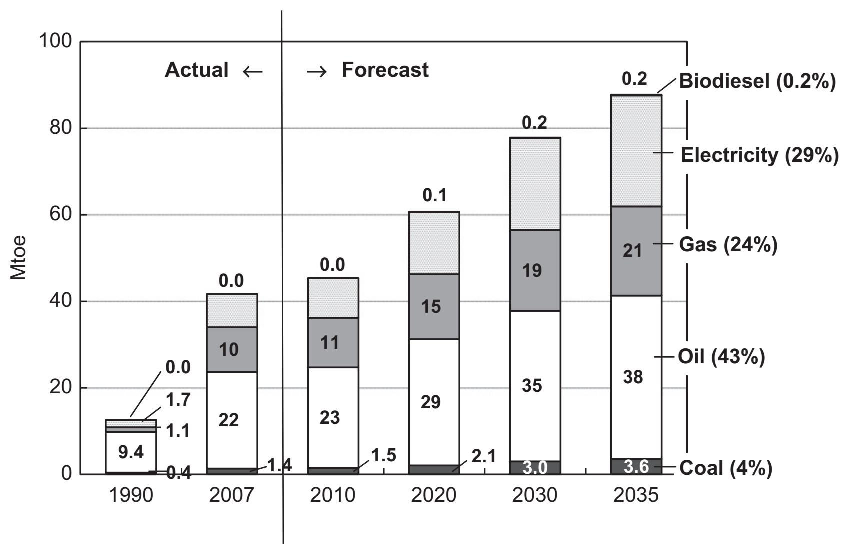

Fig. 3. Malaysia final energy demand by fuel to 2035 in the reference scenario (Mtoe).

Energy demand of other sectors (household, commercial and agriculture) grows most rapidly at 4% p.a., in line with rising living standards. Following a shift to less energy intensive sub-industry sectors, overall industry demand is anticipated to grow by only 2.5% per year during the projection period, a much slower pace than the 8% per year experienced in the past. Yet, this sector remains nonetheless the single largest end-use sector accounting for 44% of total final demand in 2035.

The combination of the expansion of pipelined gas supply, through the Peninsular Gas Utilization (PGU) project and the Natural Gas Distribution System (NGDS), and a subsidized gas pricing system for industry users contributed in the past to rapidly drive up gas demand, replacing oil in the process [33]. As a consequence, the share of gas to industry final energy demand reached 42% in 2007, a sharp increase from only 9% in 1990. In volume terms, future gas demand for the industry sector is expected to expand further. The pace of increment, however, will decelerate over the long run, in part due to a tightening between domestic supply and demand. The stagnation of offshore production from the east coast of Peninsular Malaysia, as well as additional demand from the power sector is contributing factors to the situation.

External gas supply will play an increasingly prominent role over the long run to meet rising demand from both industry and electricity generation. Apart from West Natuna B of Indonesia (117 mmscfd, beginning 2002), the Malaysia Thailand Joint Development Area (MTJDA) (293 mmscfd, beginning 2005) and the PM-3 Commercial Arrangement Area (250 mmscfd, beginning 2003), additional gas supply is being sourced from PETRONAS-Australian Gladstone LNG project at a rate of 3.5 million tons per year for 20 years, beginning 2014 [6,34–36]. In line with possible imports of LNG in the near future, Petronas, the national oil company, has already begun to plan for additional new infrastructures. The first re-gasification plant capable of processing some 3.5 million tons of LNG is anticipated to come on stream by July 2012 to ensure continuity of gas supply from the Peninsular Malaysia [37].

Along with the expansion of external gas supplies, future gas prices are expected to normalize through a gradual removal of the subsidies over the long run, thus eliminating its price competitiveness as the preferred fuel [22]. The share of gas demand by industry will settle at 38% in 2035, marginally dropping from 42% in 2007. Although the decreasing trend of industry oil demand is anticipated to continue, oil will remain one of the dominant fuels to this sector

accounting for 25% of its total energy demand in 2035, complementing gas. Electricity demand will account for the remaining share.

Demand for oil overall will increase from 22 Mtoe in 2007 to 38 Mtoe in 2035 in the reference scenario, driven mainly by the need for mobility as showed in Fig. 3. Its share will drop the most, from 53% in 2007 to 43% in 2035. Oil demand for the transport sector will increase from 13 Mtoe in 2007 to 23 Mtoe by 2035, accounting for over 60% of final oil demand throughout the projection period. Although B5 biodiesel blending is assumed to commence in 2011, its total amount will remain marginal at 0.2% of total final demand in 2035.

On the other hand, electricity consumption will expand most rapidly at 4.4% p.a. over the projection period as a result of increased industry and commercial uses and the affordability of household appliances. In the reference scenario, the share of electricity in final energy consumption will rise from 18% in 2007 to 29% in 2035 as showed in Fig. 3.

On a primary energy basis, the fuel input requirements for electricity generation is anticipated to increase its share of TPES from 32% in 2007 to 42% in 2035 and total electricity generation will rise from 101 terawatt hour (TWh) in 2007 to 325 TWh by 2035, as showed in Fig. 4. The share of coal used by the electricity sector, in the reference scenario, will increase from 30% in 2007 to 38% in 2035, backed by favorable governmental policies. Additional coal-fired power plants are coming on stream by 2015 to fulfill the growing needs of the Peninsular Malaysia region, where demand is concentrated (see Table 4) and to also replace aging gas-fired plants. Five gas-based first generation independent power producers (IPP) operating in this region, with an aggregate capacity of some 4 gigawatt (GW), will reach their life expectancy between 2015 and 2017 [38] and they will be replaced by new coal plants, causing a structural shift from gas to coal as the base load of electricity generation [23].

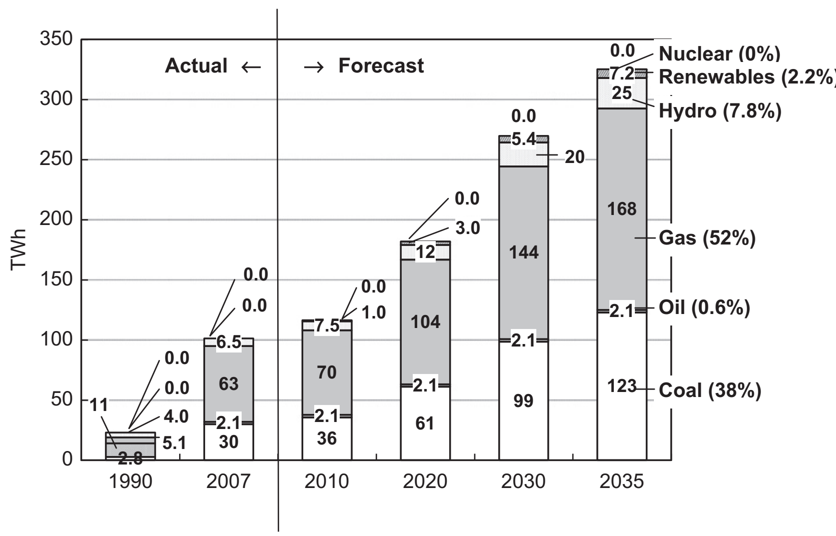

Fig. 4. Malaysia electricity generation by fuel to 2035 in the reference scenario (TWh).

Table 4
Malaysia planned power plants.

Power plant	Capacity (MW)	Year commissioned	Coal demand (million ton/year)
I. Coal-fired power plants			
Existing			
TNB—Port Klang power plant (Phase 2)	600	1988/99	1.5
TNB—Port Klang power plant (Phase 3)	1000	2001	2.5
Independent Power Producer—Sejingkat power plant	100	2000	0.3
TNB—Janamanjung power plant	2100	2004	6.0
Independent Power Producer—Pulau Bunting	700	2005	1.8
Independent Power Producer—Jimah power plant	1400	2008	3.5
TNB—Tanjung Bin power plant	2100	2007	5.7
IPP Mukah	270	2009	1.2
Future		Commissioning	
TNB Lahad Datu	300	2014	1.22
TNB Janamanjung expansion	1000	2015	n.a.
Peninsular new coal power plant	1000	2015	n.a.
II. Other planned new power plants			
Ulu Trengganu (Hydro)	250	2014/15	
Ulu Jelai (Hydro)	372	2014/15	
Bakun (Hydro)	2400	2011	
Murum Dam (Hydro)	944	2013	
Two unit in Sabah (Gas)	400	2010–2015	
Prai Power Station (Gas)	*220*	*2014 (under review)*	

Compile from: [7,22,25,39–47].

In the reference scenario, the share of gas in total electricity generation will drop from 62% in 2007 to 52% by 2035, as a result of coal expansion and penetration of renewable-based electricity. Electricity generation from hydro and renewable energy, such as solar, biomass, biogas and solid waste, will contribute to 10% of the total electricity generated in 2035. CO_2 emissions per unit of electricity generated in the reference scenario are projected to settle at 549 gCO_2/kWh in 2035.

Under a positive outlook of economic growth to 2035, the energy projections in terms of future energy mix under the Reference scenario identify several issues for long term energy security and environmental concerns that need careful attention when formulating and positioning future energy policies. The most prominent issue relates to an increase dependency on coal for electricity generation. Apart from being the less environmentally friendly choice of fuel, the other major setback of using more coal relates to its increased spending on imports. With domestic production remaining marginal or uneconomical for exploitation on a large scale, almost all the coal requirements had in the past been imported and will continue to be met by imports. Electricity generation alone currently needs 22.5 million tons of coal a year and demand is anticipated to increase with the commissioning of new coal power plants in the next five years (see Table 4). Although governmental policies of promoting coal to the detriment of gas for electricity generation could be helpful in conserving indigenous oil and gas resources it is, nonetheless, lacking as a sustainable strategy over the long run judging from its adverse implications to the economy and the environment.

Setting aside coal imports, outsourcing gas for the Peninsular Malaysia region is anticipated to increase in order to keep up with demand for electricity generation and industry uses, as discussed earlier in section 2.4. Furthermore, oil imports are anticipated to take place and the import dependency will increase from 19% in 2020 to 44% in 2035, according to IEEJ [24]. Despite the fact that domestic production of oil and gas has been more than sufficient in meeting local demand, this self sufficiency position is bound to reverse over the long run, in part due to demand growths and expectations of crude output decline. Additionally, CO_2 emissions are anticipated to increase sharply in particular from the use of coal in electricity generation. From the point of view of resource

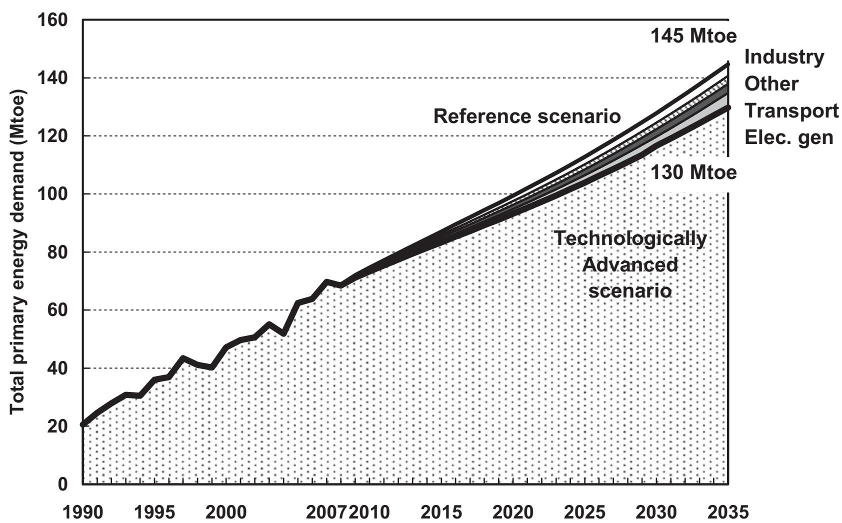

Fig. 5. Potential energy savings by sector (Mtoe).

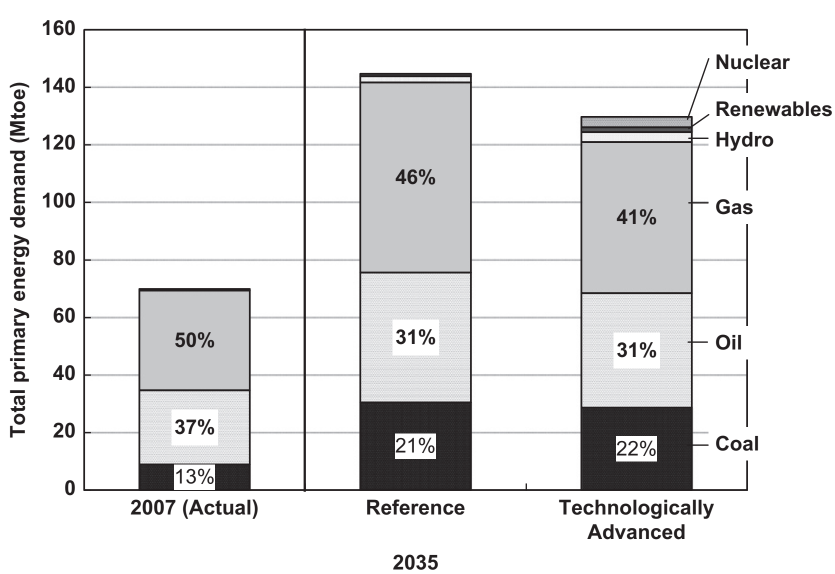

Fig. 6. Total primary energy demand by fuel in the reference and technologically advanced scenarios in 2035.

conservation, energy security and environmental protection, findings in the Reference scenario stress the imperative need for a drastic and comprehensive transformation to an energy system that emphasizes the use of renewable energy and energy efficiency.

3. Energy outlook in the technologically advanced scenario

Primary energy demand in the technologically advanced scenario is anticipated to be 130 Mtoe, 10% lower than in the reference scenario, as showed in Fig. 5. Major gains will come from electricity generation, contributing 34% or 5.1 Mtoe of the total reduction. This is followed by the industry sector at 27% (4 Mtoe), the transport sector at 21% (3.1 Mtoe), and the household and commercial sectors combined at 18% (2.7 Mtoe). On a fuel basis, the share of coal and oil to primary energy demand will remain almost unchanged in both the reference and the technologically advanced scenarios, whereas the share of gas will drop from 46% in the reference scenario to 41% in the technologically advanced scenario, following the incremental use of non-fossil resources, namely renewables and nuclear as showed in Fig. 6.

For the electricity sector, an accelerated use of renewable energy and the installation of a nuclear plant in 2030 were assumed. Major hydro, renewable energy and nuclear combined will account for 22% of Malaysia's electricity generation in 2035, leading to a drastic change to the electricity generation mix compared with the Reference scenario as showed in Fig. 7. Solar and biomass are anticipated to experience the wider and faster deployment, attributed to their vast availability and relative likelihood of further expansion. Based on our projection in the technologically advanced scenario, it is estimated that in 2035, one of every four households in Malaysia will have a solar photovoltaic system, assuming a 3 kilo-watt peak (kWp) per household installation rate. On the other hand, the share of fossil fuel electricity will drop from 90% in the reference scenario to 78% in the technologically advanced scenario.

The expansion of non-fossil electricity generation in the technologically advanced scenario will further lower CO_2 emissions per unit of electricity generated from 549 to 481 gCO_2/kWh in 2035, a drop of 13% relative to the reference scenario as showed in Fig. 8.

Overall CO_2 emissions for Malaysia will drop to 358 million - tons ($MtCO_2$) in 2035, a 56 $MtCO_2$ reduction compared with the Reference scenario as showed in Fig. 9. Half of the reduction in CO_2 emissions will come from energy efficiency improvements in the end-use sectors. This is followed by electricity generation at 26%, and fuel switching including nuclear at 23%.

The technologically advanced scenario demonstrates how a wider utilization of domestically available renewable energy sources and the promotion of energy efficiency could effectively improve Malaysia's energy intensity, reduce its dependency on

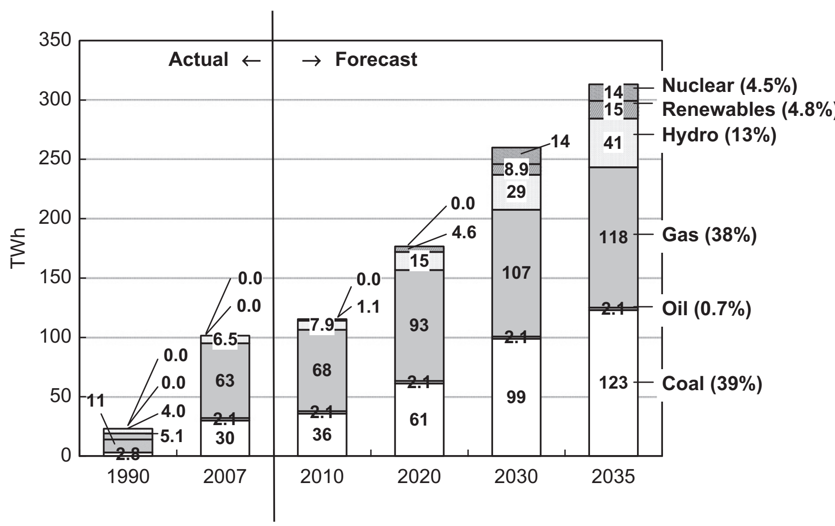

Fig. 7. Malaysia electricity generation by fuel to 2035 in the technologically advanced scenario (TWh).

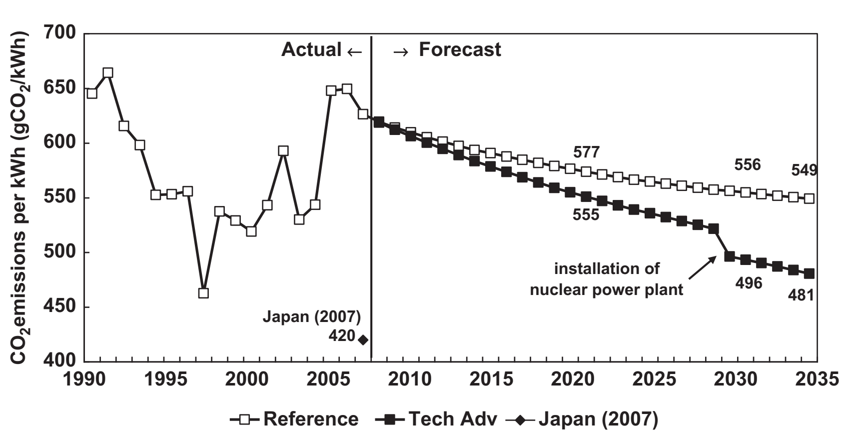

Fig. 8. Outlook of CO_2 emissions per unit of electricity produced (gCO_2/kWh).

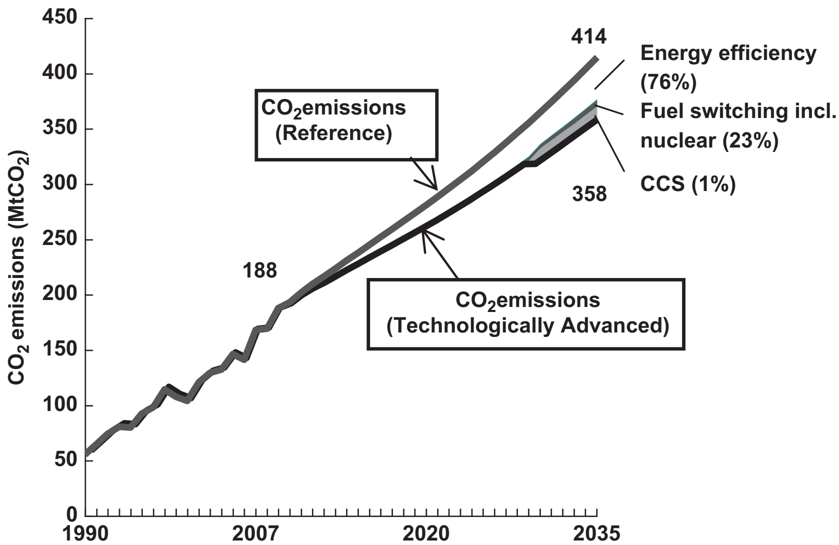

Fig. 9. Outlook of CO_2 emission reductions to 2035 ($MtCO_2$).

Table 5
Proposed feed-in tariff for RE-based electricity, compared with IPP.

Rate	Duration (year)	Rate (US$/kWh) (1)	RM/kWh	Remarks
Average electricity tariff (2008)	–	0.09	0.32	
Proposed feed-in tariff for Renewable energy				
Wind	21	0.07–0.10	0.23–0.35	
Solar PV	21	0.37–0.51	1.25–1.75	IRR 5%–12%, payback <12 yrs
Solid Waste & sewage gas	21	0.09–0.13	0.30–0.46	IRR 8%–13%, payback <7 yrs
Biomass (palm oil, agro)	16	0.07–0.10	0.24–0.35	IRR 8%–13%, payback <7 yrs
Biogas (palm oil, agro, farming)	16	0.08–0.10	0.28–0.35	
Geothermal, Ocean	21	0.08–0.13	0.28–0.46	
Mini hydro	21	0.07	0.23–0.24	
Existing buy-back rate agreed				
I. Fossil fuel				
First generation IPP	21	0.04–0.07	0.14–0.25	
Subsequent IPP (Janamanjung coal-fired plant)	n.a.	0.04	0.12	
II. Renewable energy				
Landfill gas	15	0.05	0.17	
Palm oil biomass	21	0.06	0.21	

Compile from: [27,29,38,51,53].
(1) Based on US1=Malaysian Ringgit 3.4245, average for 2009.

fossil fuels and also reduce CO_2 emissions by 2035. It demonstrates the important role of renewable energy and technology improvements in addressing energy security as well as environmental issues. Increasing the use of renewable energy has other economic benefits: for instance it will reduce the financial burden of subsidies the government is providing to gasoline and diesel for different sectors [48].

4. Suggestions on sustainable energy strategies

Our projections in Section 3 indicate that advanced technological measures, such as efficiency improvements and fuel switching to renewable or nuclear, appear to be effective in pursuing a sustainable energy system in Malaysia over the long run. In order to realize the benefits of using renewables and improved energy efficiencies, the government practically needs to speed up the implementation of vital supportive policies. The following section reviews the current governmental policies, the progresses and barriers in the area of renewables and energy efficiency, and suggests a required approach to support the promotion of energy efficiency and the further development of renewables.

Promoting the use of renewable energy in power generation in Malaysia began in 2001 with the Small Renewable Energy Power Program (SREP). Under this program, the utilization of all types of renewable energy was permitted, including biomass, biogas, municipal solid waste, solar, small hydropower and wind. SREP developers can sell up to 10 MW to the national grid system [49] through the Renewable Energy Power Purchase Agreement (REPPA). By 2009, 17 SREP projects with a combined generation capacity of 116.4 MW were licensed. Of this, only five projects have actually commenced operation and sold electricity to the national grid system [50]. There has been little progress and the program suffers from the current policy in which the buy-back rate agreed in REPPA for renewable-based electricity is insufficient [7,51]. To address this problem, the government has seriously studied the introduction of feed-in tariffs (FIT) over the last two years and proposed a buy-back rate in the range of US$0.07 to US$0.51 per unit of electricity, differentiated by type of renewable energy sources (see Table 5). In general, the

proposed buy-back rates for renewable energy based electricity are higher than the rates agreed in the past for other IPP, as summarized in Table 5. Among the renewable energy sources, FIT for solar generation is the highest on account of its higher initial investment, which currently averaged RM23,703 per kWp [29]. Implementing FIT in Malaysia would be a timely and effective measure to address the low buy-back rate issue and give the market a positive signal. A study by the International Energy Agency (IEA) [52] concludes that FIT provides the highest market growth for renewables and that the cost per kWh tends to be lower under FIT than under standard renewable portfolio schemes. A careful design and a periodic review of FIT are, however, necessary to ensure that the objectives of developing renewables are achieved at the lowest cost to society.

On promoting the use of biodiesel, the government launched in 2006 a 1-year trial program using palm oil as the feedstock for a selected group of users and had initially planned to regulate B5 blending nationwide the following year. Unfortunately, the plan was deferred due to high palm oil prices and a lack of government commitments [15]. As the world's second largest palm oil producer (17.6 million tons in 2009) and exporter (16 million - tons in 2009) [54], Malaysia can easily meet its 5% blending of palm oil based biodiesel, which only requires an estimated 280,000 ton per annum [15]. Promoting the use of palm oil based biodiesel would benefit both the palm oil and the transport sectors. It would be beneficial to revive the currently stagnating domestic biodiesel sector [55] because a promising biofuel market may contribute to the development of a second generation biofuel utilizing palm oil biomass as feedstock [56–59]. Additionally, the use of biodiesel helps to reduce oil demand and CO_2 emissions, thus improving overall energy security and environmental sustainability. Nevertheless, with current high palm oil prices, selling B5 biodiesel in domestic market will remain uncompetitive and unrealistic without significant policy supports and an appropriate pricing strategy. The recently announced new subsidy for the setting up of blending facilities and necessary associated infrastructure required for the marketing of B5 blending [60] is a good start towards the nationwide sale of B5. Nonetheless, in order to support a successful B5 program in Malaysia, the provision of proper incentives and subsidy, the setting of appropriate pricing of B5 blend, and the establishment of regulatory targets and mandate are urgently required.

Energy efficiency is another key area that is gaining increased attention from the government. In its New Energy Policy, energy

Table 6
Energy efficiency improvement projects under the CDM.

Project detailas		
1. Factory energy efficiency improvement project in Malaysia (PHAAM, PCOM(SA), PEDMA, MEDEM)		
To reduce greenhouse gas (GHG) emissions through reduction of electricity and natural gas consumption, by introducing 15 specific measures from among eight different types of energy efficiency improvement measures at five factories in Malaysia.		
〈Project information〉		
Project site	:	Panasonic HA Air-Conditioning Malaysia Sdn Bhd (PHAAM)
	:	Panasonic Compressor Malaysia Sdn Bhd (PCOM(PJ))
	:	Panasonic Compressor Malaysia Sdn Bhd (PCOM(SA))
	:	Panasonic Electronic Devices Malaysia Sdn Bhd (PEDMA(SW))
	:	Panasonic Electronic Devices Malaysia Sdn Bhd (PEDMA(SA))
Amount of reductions	:	6474 tones of CO_2 per annum
Commencement date	:	April 1, 2006
Crediting period	:	April 1 2007 to March 31 2017
〈Summary of energy efficiency measures〉		
Energy efficiency improvement measures in air conditioning		
Energy efficiency improvement measures in utility		
Energy efficiency improvement measures in power distribution facility		
2. Factory energy efficiency improvement project in Malaysia (MAPREC, PRDM, PSCDDM, PAVCJM, PCM)		
To reduce GHG emissions through reduction of electricity and natural gas consumption by introducing 15 specific measures from among five different types of energy efficiency improvement measures at five factories in Malaysia.		
〈Project information〉		
Project site	:	Matsushita Precision Capacitor Malaysia Sdn. Bhd. (MAPREC)
	:	Panasonic Refrigeration Devices Malaysia Sdn. Bhd. (PRDM)
	:	Panasonic Semiconductor Discrete Devices (M) Sdn. Bhd.(PSCDDM)
	:	Panasonic AVC Networks Johor Malaysia Sdn. Bhd. (PAVCJM)
	:	Panasonic Communications Malaysia Sdn. Bhd. (PCM)
Amount of reductions	:	1312 tons of CO_2 per annum
Commencement date	:	April 1, 2006
Crediting period	:	April 1 2007 to March 31 2017
<Summary of energy efficiency measures>		
Energy efficiency improvement measures in air conditioning		
Energy efficiency improvement measures in utility		
3. Factory energy efficiency improvement in compressed air demand and supply in Malaysia		
To reduce GHG emissions through reduction of electricity consumption by introducing energy efficient measures to reduce the demand of compressed air at the selected project site.		
〈Project information〉		
Project site	:	DENSO (Malaysia) Sdn. Bhd.
Amount of reductions	:	173 tons of CO_2 per annum
Commencement date	:	April 1, 2007
Crediting period	:	December 1 2007 to November 30 2014
〈Summary of energy efficiency measures〉		
Adopts high efficient air nozzles, blowers to replace existing equipments		
Upgrade of existing air compressors to reduce air consumption		

Compile from: [63]

efficiency is positioned as one of the key planks alongside with renewable energy, to target cumulative energy savings of 4 Mtoe by 2015 through the implementation of the National Energy Efficiency Master Plan [22]. The government has in the past implemented a number of projects targeting efficiency improvements in the industry sector (the largest end-use sector accounting for 46% of final energy demand in 2007). One of these, the MIEEIP project identified potential energy savings of 61.7 thousand tons of oil equivalent (ktoe) per year (approximately 0.3% of industrial final energy demand in 2007) through its energy audit exercises on eight energy intensive industrial sectors (namely wood, food, glass, cement, rubber, pulp and paper, iron and steel, and ceramic). The MIEEIP project contributed to the removal of some barriers, in particular awareness creation and capacity building in important areas such as benchmarking, best practices, audits and demonstration of energy efficiency processes and technology [61]. The industry's effort to improve its energy efficiency, however, has been minimal and lacked long term continuity. Hefty energy subsidies on fuels and electricity by the government [48] and the lack of policies for the promotion and implementation of energy efficiency appear to discourage efforts to improve energy efficiency. Therefore, establishing a fundamental energy efficiency law to govern energy use and conservation would be the first and foremost step required towards promoting energy efficiency in Malaysia. The law should outline comprehensive energy conservation measures for all sectors. The measures could include, for example, energy saving targets for the eight energy intensive industries, mandatory energy efficiency standards for household equipments, for vehicles and buildings, fiscal incentive and support, etc.

Technology transfer through clean development mechanism (CDM) [62], regional and international technology cooperation are important means that help to promote the use of renewable energy and energy efficiency. In terms of CDM, there are 85 registered projects with Malaysia as the host party which potentially yields an annual CO_2 emission reduction of 5,185,289 ton as of October 2010 [63]. These projects are comprised not only of electricity generation using renewable energy sources such as palm oil biomass, but also include factories energy efficiency improvement initiatives. Table 6 summarized three CDM projects with Japan as the counterpart on factory energy efficiency improvements. In addition to CO_2 emission reductions, these projects help accelerate the penetration of presently best available technologies into the domestic industry sector, the transfer of management know-how and capacity building, and potentially yield significant technological spillovers [63].

Promoting technology transfer through regional or international cooperation is also an important strategic option to consider. In the Japan-Malaysia Cooperation Initiative for Environment and Energy Statement of April 2010, both countries agreed to strengthen cooperation in the areas of environment and energy, for instance in energy conservation and renewable energy [64]. The recent technical cooperation in capacity building for nuclear energy development with Japan represents another positive step for the transfer of new technologies to Malaysia [64,65]. Additionally, technical cooperation on advanced clean coal technologies such as, ultra-super-critical-pulverized coal combustion or integrated coal gasification combined cycle (IGCC) could be beneficial taking into account the possible expansion of coal electricity generation in Malaysia.

Although Malaysia pledged to reduce its carbon emissions intensity of GDP by 40% from 2005 levels by 2020 [66], domestic energy efficiency efforts and fuel switching to renewable energy would remain insufficient to achieve this ambitious target. Promoting technology transfer through CDM, regional or international technology cooperation in the fields of energy efficiency and electricity generation will not only benefit the development of these areas, it will also lead to energy security, economic growth as well as substantial reductions in CO_2 emissions.

5. Conclusion

This study analyzed a low carbon society outlook for Malaysia to 2035 combining the use of renewable energy with improved energy efficiencies across all sectors. The Reference scenario projected a steady growth of Malaysia's economy with a decreasing yet sustained industry component. From an energy perspective, the Reference scenario projects a persistent dependence on fossil fuels in Malaysia's energy system and an increasingly important role for coal in electricity generation. Overall, the Reference scenario depicts an unsustainable development given increasing spending on energy imports for coal in particular, and oil and gas in the near future, as well as an increasing trend for CO_2 emissions. From the point of view of energy security and environmental protection, it is clear that concerted actions to alleviate the adverse implications from the persistent dominance of fossil fuels are needed. An alternative scenario, the Technologically Advanced scenario, demonstrates how a more extensive use of renewable energy and the promotion of energy efficiency could effectively address the over reliance on fossil fuels and reduce CO_2 emissions. Domestically, speeding up the implementation of vital policies such as FIT and B5 blends, new regulations to govern and promote energy efficiency, as well as the prompt execution of planned energy efficiency measures for households, industry and buildings are necessary to drastically transform the current energy system to one that emphasizes the use of renewable energy and efficiency improvements. Internationally, technology transfer through CDM, regional or international cooperation are strategic means to speed up the penetration of best available and advanced technologies into Malaysia for substantial reduction in both energy use and CO_2 emissions.

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